Technical Research Note 206

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EFFECT OF DISPARITY IN PHOTO SCALE AND ORIENTATION ON CHANGE DETECTION

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FOREWORD

The Surveillance Systems research program of the U. S. Army Behavioral Science Research Laboratory has as its objective the production of scientific data bearing on the extraction of information from surveillance displays and the efficient storage, retrieval, and transmission of this information within an advanced computerized image interpretation facility. Research results are used in future systems design and in the development of enhanced techniques for all phases of the interpretation process. Research is conducted under Army RDT&E Project 2Q662704A721, "Surveillance Systems: Ground Surveillance and Target Acquisition Interpreter Techniques," FY 1969 Work Program.

BESRL research in this area is conducted as an in-house research effort augmented by research contracts with organizations selected as having unique capabilities and facilities for research in aerial surveillance. The present study was conducted jointly by personnel of the Boeing Company and of the Behavioral Science Research Laboratory under program direction of A. H. Birnbaum.

The INTERPRETER TECHNIQUES Work Unit undertakes the development of methods and procedures which maximize the accuracy, completeness, and speed with which intelligence information is derived from imagery, both conventional aerial photographs and the products of advanced sensor techniques. The present publication reports on a study of the need for devices to rectify disparity in photo scale and orientation in comparative-cover photos as means of facilitating detection of change in the status of targets in the area.

J. E. UHLANER, Director
U. S. Army Behavioral Science
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EFFECT OF DISPARITY IN PHOTO SCALE AND ORIENTATION ON CHANGE DETECTION

BRIEF

Requirement:

To determine the importance of incorporating photo scale rectification and rotational capability in display systems for image interpreters concerned with detecting changes in comparative cover aerial imagery.

Procedure:

The experiment assessed the effects for three levels of scale discrepancy (1:1, 2:1, and 4:1), three levels of orientation misalignment (0°, 90°, and 180°) and two different time limits (3 minutes and 6 minutes) on the completeness and accuracy of change detection. The experiment was conducted under two requirements, one in which the interpreter detected change in objects characterized only as target or non-target, the other requiring identification of the target as belonging in one of nine categories. Subjects were 36 student image interpreters at the U. S. Army Intelligence School.

Findings:

Significant decrements in both completeness and accuracy of target change detection were associated with scale disparity and with orientation misalignment when target identification was not required.

When target identification was required, scale discrepancy resulted in significant decrement in accuracy as well as completeness, whereas orientation misalignment resulted in lower completeness but not lower accuracy.

Completeness but not accuracy of change detection with or without target identification was higher with the longer time limit.

Utilization of Findings:

Inclusion of scale rectification and orientational alignment capabilities in systems used to display comparative-cover imagery was strongly supported by the results obtained, and has been recommended for operational facilities.

EFFECT OF DISPARITY IN PHOTO SCALE AND ORIENTATION ON CHANGE DETECTION

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EFFECT OF DISPARITY IN PHOTO SCALE AND ORIENTATION ON CHANGE DETECTION

THE PROBLEM

A frequent and important requirement of image interpreters is to determine whether changes have occurred in a given area since prior photo coverage was obtained. Such "change detection" usually concerns possible change in the presence or deployment of targets. The interpreter's task is assumed to be easier--and his performance better--when the photos he is comparing are the same scale, taken from the same angle, and under similar weather and lighting conditions, in short, when they are comparable in every respect except for possible change in content. This ideal state seldom occurs. Nor can early and late photos be made in every way comparable. However, photo scale and photo orientation can be manipulated to compensate for much of the discrepancy in the comparative cover.

The objective of the present study was to estimate the extent to which the completeness and accuracy of interpreters' reports of change are dependent on the essential equivalence of the imagery being compared, and to determine the desirability of incorporating scale rectification and rotational capability in systems for displaying comparative cover to interpreters. A secondary objective was to establish the amount of scale disparity in comparative-cover photos the interpreter can tolerate before his performance is adversely affected. By measuring interpreter performance at various points along the scale-discrepancy continuum, the approximate point at which scale rectification should be a display system requirement can be calculated. With respect to misalignment, interpreters, given free access to the two photographs of a comparative pair, will frequently manipulate the two pictures, orienting one relative to the other so that the most direct point-to-point comparison can be made. When photos are not amenable to manual manipulation, special devices for orienting one or both photos may be part of the display system, or the interpreter may have to perform his analysis with whatever misalignment exists. Mental processes similar to those postulated by Boynton et al[1] as being involved in making same-different form judgments of adjacent pair members appear to be equally appropriate for the photo interpreter making target change judgments:

[1] Boynton, R. M., C. L. Elworth, R. Monty, Judith W. Onley, and C. L. Klingberg. Overlay as a predictor of form discrimination under suprathreshold conditions. Technical Report RADC-TR-61-99. Rome Air Development Center. June 1961.

"It is suggested that the ability of human beings to judge whether two forms are of the same or different shape depends upon brain processes which in effect allow for some kind of internal overlap comparison. Such a comparison would require operations by a cerebral computer wi ch somehow 'rotates' the coded representation of the form and allows areal adjustments prior to the same-different test. Such 'rotation' is difficult under impoverished .iewing conditions but becomes relatively easy and natural under good viewing conditions, where 'rotation' is in effect automatic and difficult to inhibit, but takes a finite time." (Page 43).

In the present study, three levels of scale disparity and three levels of orientation misalignment were selected for investigation. There seems ample evidence to support a generalization that the greater the number and complexity of mental manipulations required in making a judgment, the longer it will take to arrive at a judgment. Thus, comparisons requiring a single lateral translation of comparison data where no scale or orientation discrepancy exists could presumably be accomplished more rapidly than if magnification and/or rotation were also required. Since potential differences in rate of information extraction could well be obscured if subjects were given unlimited time to perform the task, performance measures were obtained for two different time limits to permit comparison of output rate for the various combinations of scale and orientation discrepancy.

METHOD

Experimental Design

The three levels of scale discrepancy included one in which the scale of each of the two images of a comparative pair were t .e same (Δ scale = 1 : 1), one in which the scale of the earlier image was one-half that of the later (Δ scale = 2 : 1), and one in which the earlier coverage was one-fourth that of the later (Δ scale = 4 : 1).

The first of the three levels of rotational discrepancy was zero (Δ orientation = 0°); that is, the flight path of the aircraft obtaining the later imagery was in the same direction as during the flight in which the earlier imagery was acquired. The 90° discrepancy condition (Δ orientation = 90°) was representative of an imagery pair produced when the flight paths of the two reconnaissance sorties were perpendicular to each other. The 180° discrepancy condition (Δ orientation = 180°) was comparable to comparison photos obtained from aircraft flying the same flight path but in the opposite direction.

Two time limits, three minutes and six minutes, were selected as being sufficiently long to provide an adequate sampling of interpreter performance and disparate enough to permit differential output rates to be accurately reflected in the performance measures.

The 18 experimental conditions are shown schematically in Figure 1. To distribute the effects associated with individual differences and differences in photo-pair difficulty equally across all treatment conditions, subjects were assigned to the various treatment combinations according to the two orthogonal Latin square matrices shown in Table 1. Each subject participated under each experimental condition and saw each of the 18 photo pairs once. Each photo pair was viewed by two different subjects under each of the treatment conditions.

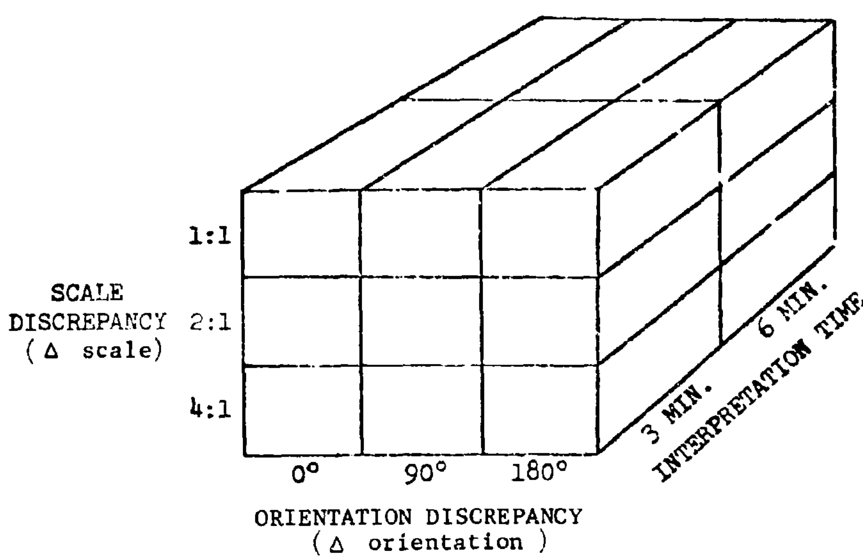

Figure I. Schematic representation of experimental conditions investigated

Table 1

ASSIGNMENT SCHEDULE FOR SUBJECT/PHOTO COMBINATIONS[a]

Photo Pair No.	Group 1 SUBJECT NUMBERS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1	3	17	2	9	11	16	10	18	15	7	14	5	12	8	6	4	13
2	17	2	4	1	12	10	15	11	16	18	13	7	8	6	5	9	3	14
3	4	1	3	17	10	12	14	9	7	16	15	13	6	8	18	5	2	11
4	3	17	2	4	11	9	10	12	15	13	14	18	7	5	6	8	1	16
5	18	7	16	14	5	8	12	17	13	3	4	15	1	11	2	10	6	9
6	7	18	13	15	17	6	11	5	4	14	16	3	12	2	9	1	8	10
7	6	5	8	13	15	16	7	14	3	4	1	2	10	9	12	11	18	17
8	15	13	7	18	6	17	9	8	14	1	2	16	11	3	10	4	5	12
9	13	16	14	6	1	15	8	3	9	11	17	10	18	7	4	2	12	5
10	8	14	5	7	16	2	13	15	17	10	12	9	4	18	1	3	11	6
11	16	8	18	5	14	1	6	13	12	9	11	17	2	4	3	7	10	15
12	14	15	6	16	2	13	5	4	11	17	10	12	3	1	7	18	9	8
13	9	11	12	10	18	3	4	2	5	7	8	6	13	15	17	14	16	1
14	12	10	9	11	4	18	3	7	8	6	5	1	17	14	16	13	15	2
15	10	12	11	9	7	4	2	1	6	8	18	5	16	13	15	17	14	3
16	11	9	10	12	3	7	1	18	2	5	6	8	15	17	14	16	13	4
17	2	4	1	3	8	5	18	6	10	12	9	11	14	16	13	15	17	7
18	5	6	15	8	13	14	17	16	1	2	3	4	9	10	11	12	7	18

Photo Pair No.	Group 2 SUBJECT NUMBERS 19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	1	4	2	17	13	16	11	15	5	8	6	12	18	14	10	7	3	9
2	4	2	17	3	15	14	12	13	9	6	8	5	11	18	7	1	1	10
3	2	17	3	1	16	13	9	14	8	5	18	6	12	7	11	10	4	15
4	17	3	1	4	14	15	13	16	6	7	5	8	10	11	9	18	2	12
5	13	15	10	11	5	17	2	6	18	16	14	7	9	4	12	3	8	1
6	16	14	12	9	8	6	1	17	15	18	7	13	3	10	4	11	5	2
7	11	12	9	10	2	1	17	3	14	13	16	15	4	8	5	6	18	7
8	10	11	14	16	17	5	3	8	7	15	13	18	2	9	1	12	6	4
9	5	16	8	15	18	4	14	7	2	12	10	17	1	3	6	9	11	13
10	15	6	16	13	3	18	4	1	12	10	17	11	7	2	8	5	9	14
11	6	13	15	14	4	7	16	2	10	17	11	9	8	5	18	1	12	3
12	14	5	13	8	7	3	15	18	17	11	9	1	6	12	2	4	10	16
13	18	8	6	7	9	12	10	11	1	4	2	3	13	16	14	17	15	5
14	12	18	7	5	11	10	8	9	3	2	4	14	16	1	17	15	13	6
15	8	7	18	6	12	9	5	10	4	1	3	2	14	17	15	13	16	11
16	7	9	5	18	10	11	6	12	16	3	1	4	17	15	13	2	14	8
17	3	1	4	2	6	8	7	5	11	9	12	10	15	13	16	14	17	18
18	9	10	11	12	1	2	18	4	13	14	15	16	5	6	3	8	7	17

[a]Numbers in the table represent the 18 experimental conditions diagrammed in Figure 1.

Subjects

Subjects were 36 enlisted men attending the Image Interpretation course at the U. S. Army Intelligence School, Fort Holabird, Maryland. All were at approximately the same stage in their training program, having completed 12 weeks of the fifteen-week course.

The Experimental Task

The task to be performed was the preparation of written reports for 18 different pairs of comparative-cover scenes in which tactical military targets appeared. The process of change detection included target detection and coordinate localization and identification of targets.

Change Detection without Target Identification. This level of identification required only that the interpreter state whether an object was a target or a non-target. Having determined a detected object to be a target, the interpreter then checked the comparative photo to determine whether the target was present or absent at the same location. If he found the target present only on the earlier imagery, he labeled it "Gone" on the second photo; if he found the reverse, he labeled the target "New" on the second photo. If the object was seen as present in the same location on both photos, the interpreter was required to make a same-different judgment prior to assigning a change status of "Unchanged" or "Replaced." Erroneous change status assignments could thus result from one or more of several errors: failure to detect the presence of a target or targets, failure to distinguish between target and non-target objects, detecting an object where there was none (inventive errors), failure to translate accurately target locations in comparing photos, and failure to make the correct same-different discrimination.

Change Detection with Target Identification. At this level, the interpreter was required to identify the target as belonging to one of nine target categories listed on the Response Code Sheet (Figure 2). Having detected and identified a target, he proceeded to assign the change status designation as at the detection level. In addition, where a target was uniquely identifiable, the change status "Moved" was applicable if the target had been repositioned within the same general area. All sources of erroneous change status assignment cited above were applicable to the identification level of response, plus misidentification of detected targets.

The method of evaluating interpreter performance placed maximum emphasis on the change detection aspect of the task. In scoring, a change status assignment was counted as correct only when the total present-absent and same-different comparison had been accurately performed.

RESPONSE CATEGORIES	CONFIDENCE LEVELS	CHANGE STATUS
1. Tanks (includes M41, M48, M60)	C -- Certain	U -- Unchanged
2. SP Howitzers & Guns (includes M42, M44, M53, M55, M56, M108, M109)	FS -- Fairly Sure	M -- Moved (within area)
3. Armored Personnel Carriers (includes M59, M113, M114)	D -- Somewhat Doubtful	N -- New
4. Trucks - 3/4 Tons & Less (includes M37, M38, M151)	G -- Best Guess	G -- Gone
5. Trucks - 2-1/2 Tons & Greater (includes M34, M35, M36, M41, M54, M55, M49)	? -- Something	R -- Replaced
6. Trailers & Semi-Trailers (includes Cargo, Water, Gas, Tank Transport)		
7. Engineering Equipment (includes Cranes, Graders, Scoops, Tractors, etc.)		
8. Aircraft (includes fixed & rotating wing)		
9. Others (includes Wrecker, M543 & M62; Truck Tractors, M52 & M123; Recovery Vehicle, M88; does not include Tents, buildings, stock piles, roads, railroads, rivers)		

Figure 2. Response Code Sheet used in the experiment

Materials and Equipment

Photography. From imagery available in the Technical Support Branch Film Library of BESRL's Support Systems Research Division, 18 pairs of comparative-cover aerial photography were selected. Criteria considered in selection were:

1. That the terrain common to both members of a photo pair (overlap area) constitute the major portion of each when equated for scale and format size.

2. That the original photo scale permit the photo reduction necessary to obtain the required scale discrepancies without reducing targets to a size obviously below detection threshold.

3. That the original photo quality be such that enlargement to four times the original scale would not introduce excessive degradation.

4. That a representative range and frequency of target types be included.

5. That the types of terrain depicted be representatively varied.

6. That the selected sample contain approximately equal proportions of photo pairs in which the scale of the earlier photo was 1/4, 1/2, equal to, twice, and four times that of the later photo.

All the images were black and white vertical photos of Camp Drum, New York. All photos had been taken during the summer, except for one pair in which both photos were taken in winter with a fairly uniform snow cover present. Number and distribution of target types and additional descriptive data for the 18 pairs (original scale ratios, image quality, time lapse, type of change, etc.) are given in Appendix A (Table A-1).

To maintain equal ground area coverage in the two photos of a pair, photo size was permitted to vary with the adjustment necessary to arrive at the desired scale discrepancy. Thus, whereas the most recent coverage (designated P_2) was always adjusted to and displayed in a 9" x 9" format, the earlier coverage (P_1) was displayed in 9" x 9", 4.5" x 4.5", and 2.25" x 2.25" format, depending on the scale discrepancy to be achieved.

The two comparison prints were positioned and affixed to the opposing inner surfaces of a manila folder. When the folder was properly oriented and opened, P_2 was seen on the right and P_1 on the left. P_2 was always positioned parallel to the lower and right edges of the folder and oriented so that its identification number was in the lower right corner. P_1 of each pair was secured on the opposing surface and so aligned as to produce the desired orientation discrepancy relative to P_2. Figure 3 illustrates the range of discrepancies included in the investigation.

(A) Δ scale = 1:1;
Δ orientation = 0°

(B) Δ scale = 2:1;
Δ orientation = 90°

(C) Δ scale = 4:1;
Δ orientation = 180°

Figure 3. Illustration of comparative photo pair presented at each of the scale/orientation discrepancy levels.

Other Materials. A Response Code Sheet (Figure 2) established the nine target categories to be used in reporting the identification of targets detected, and the five types of target change to be determined and assigned to each target reported. Confidence ratings were included in order to simulate more closely operational procedures in which it is common practice for interpreters to rate their confidence in the information they report. An Immediate Report Form (Figure 4) was provided with each photo pair to standardize the target reporting format and identify subject, experimental condition, and stimulus material.

Each subject was issued a 9" x 9" transparent celluloid target localization grid ruled off into 144 consecutively numbered 3/4" square cells. When overlaid on the right-hand photo of each comparative pair, the grid provided the numerical reference system for reporting the location of detected targets. Interpreter keys for the identification of U. S. military vehicles were made available to all subjects.

IMMEDIATE REPORT FORM

Name ______________________ Man No. ______________________

Date ______________________ Perf. Meas. No. ______________

Item No.	Object Name	Change Status	Confidence	Target Location	Time

Figure 4. Reproduction of Immediate Report Form used in the experiment

Procedure

Subjects were tested in two groups of 18 each. The testing was conducted in the regularly assigned classrooms at the U. S. Army Intelligence School during normal duty hours. Upon arrival, the subjects were briefed on the general purpose of the test program and the role they were to play in it. The need for rigid adherence to the imposed test controls and procedures was emphasized. They were reassured that, although maximum performance was sought, the results of the testing would not appear in their permanent records nor influence their class grades.

The test materials were then distributed. Each subject received 18 manila folders, each containing one pair of comparative-cover photographs, and 18 Immediate Report Forms. Each subject received one transparent 144-cell 9" x 9" target location grid, one Response Code Sheet, and a set of interpreter keys for U. S. military vehicles.

A detailed explanation and demonstration of the test procedures to be followed was then presented. Major points were:

Orientation of Test Imagery and Target Localizing Grid. Subjects were cautioned to be sure that the small tab on the folder was oriented to the left-hand side of the folder. To report the location of a detected target they were to position the 144-cell transparent grid over the right-hand photo (which was always the same size as the grid) with the lower left corners of grid and P_2 photo coincident.

Order of Presentation. Subjects were instructed to proceed systematically from photo pair 1 through pair 18 so that order of presentation was the same for all subjects.

Time Limits. Subjects were to stop working when their allotted time was up, and not begin inspection of any pair of photos until told to do so. The time interval under which each subject was working appeared on the front of his folder. When the end of the 3-minute limit was announced, all subjects working under the 3-minute condition were to stop working on one pair and wait until the beginning of the next interval. A similar procedure was followed by those working under the 6-minute limit.

Interpretation Aids. No magnifiers or optical aids were to be used during the test session. This procedure insured preservation of the established scale discrepancy between P_1 and P_2 of each pair. Interpreter keys could be used as needed for target identification, but were to be relied upon as infrequently as possible.

Recording Responses. Each target detected was to be numbered and recorded sequentially on the Immediate Report Form. Target location was reported as the cell number on the transparent grid overlay within which the target(s) appeared. Multiple target entries were permitted where targets were tightly clustered and were all of the same category, but

each such entry had to contain a notation of both number and type (e. g., 6 x 1 indicated six tanks). Each target detected had to be identified as belonging to one of the nine target categories listed on the Response Code Sheet. A change status statement (Unchanged, Gone, New, Moved, or Replaced) had to accompany each detection listed.

Individual responses were scored by comparing each report of a target location, identification, and change status with "interpreter truth" data provided by a team of experts in the U. S. Army Behavioral Science Research Laboratory. The interpreter truth for each target on a photo pair--target location and change status--was encoded and transcribed on punched cards. The responses to these targets as reported by each subject were similarly encoded and transcribed from the Immediate Report Forms to the same cards. Inventive errors were identified and entered separately. Comparison of the transcribed responses given by the subject with interpreter truth yielded quantitative data on 1) number of targets correctly detected (and by subtraction, number omitted); 2) number of correctly detected targets which were correctly identified and the number incorrectly identified; 3) number of correct and incorrect change status assignments; and 4) number of inventive errors committed along with number of erroneous identifications and change status designations associated with the inventive error.

Evaluative Measures

From the response data available, evaluations of interpreter performance were derived for application in assessing the effects of the independent variables. Separate measures of interpreter performance were computed for change status detection without identification of target and for change status detection requiring target identification.

<u>Change Status Completeness</u>. The completeness of interpretation is the ratio of the number of correct change status responses to the total number of correct change status responses possible. In equation form:

$$\text{COMPLETENESS} = \frac{\text{Number of Correct Change Status Responses}}{\text{Total Possible Correct Change Status Responses}}.$$

<u>Change Status Accuracy</u>. The accuracy of interpretation is the ratio of the number of correct change status responses to the total number of change status responses (both correct and incorrect) reported by the interpreter subject. In equation form:

$$\text{ACCURACY} = \frac{\text{Number of Correct Change Status Responses}}{\text{Total Number of Change Status Responses Reported}}.$$

To provide comparable performance measurement units from photo pairs containing different numbers of targets, the completeness and accuracy scores of each subject were averaged over all photo pairs viewed under each experimental condition to yield mean performance figures for each treatment condition.

RESULTS

Completeness of Change Detection

<u>Change Detection without Target Identification</u>. Mean completeness scores for change detection when target identification was not required are presented in Table 2. Significant differences ($p < .01$) were associated with main effects for each of the independent variables (see analysis of variance summary table B-1, Appendix B). No significant interactions between variables were found.

As anticipated, more complete change detection reports resulted from increased interpretation time. Although the absolute magnitude of the difference between 32 percent change detection in 3 minutes and 40 percent in 6 minutes is only 8 percentage points, this increment represents a performance improvement of 25 percent. Consistent and reliable performance differences of this magnitude may well have practical as well as statistical significance.

The effect of increasing scale discrepancy was to degrade completeness of change detection systematically. Whereas with photos of equivalent scale approximately 40 percent of the target changes were detected, this figure was reduced to 36 percent when the scale of one photo was one-half that of the other, and dropped to 32 percent when the scale difference was four to one. Duncan's new multiple range test revealed that each additional increment of scale disparity produced a statistically significant ($p < .05$) decrement in completeness.

Completeness of target change detection also declined with increased rotational misalignment between members of a comparative photo pair. Rotating one photo 90° relative to the other resulted in a statistically significant ($p < .05$) average performance decrement of approximately 4 percent (40% vs 36%). Increasing the orientation discrepancy from 90° to 180° reduced completeness to approximately 33 percent, although this decrement was not statistically different from performance with the 90° discrepancy. Clearly, interpreters can benefit from having comparative cover displayed in the proper orientational alignment.

<u>Change Detection with Target Identification</u>. Mean completeness scores for change detection when target identification was a required element of the interpreter's task are presented in Table 3. The results of the analysis of variance are presented in Table B-2. As might have been predicted in view of the contingency relationship between target detection and subsequent target identification, the analysis also indicated significant performance effects for each of the three experimental variables.

An increase in completeness from 26 percent to 32 percent resulted from increasing interpretation time from 3 to 6 minutes, a relative performance improvement of about 25 percent.

Table 2

MEAN COMPLETENESS SCORES FOR CORRECT CHANGE DETECTION WITHOUT TARGET IDENTIFICATION

Orientation Misalignment	Photo Scale Disparity											
	3-Minute				6-Minute				Combined			
	1:1	2:1	4:1	M	1:1	2:1	4:1	M	1:1	2:1	4:1	M
0°	.386	.378	.292	.352	.517	.445	.397	.453	.451	.411	.344	.402
90°	.352	.281	.270	.301	.421	.437	.379	.412	.286	.359	.324	.357
180°	.363	.280	.264	.302	.391	.339	.311	.347	.377	.309	.288	.325
M	.367	.313	.275	.318	.443	.407	.362	.404	.405	.360	.319	.361

Table 3

MEAN COMPLETENESS SCORES FOR CORRECT CHANGE DETECTION WITH TARGET IDENTIFICATION

Orientation Misalignment	Photo Scale Disparity											
	3-Minute				6-Minute				Combined			
	1:1	2:1	4:1	M	1:1	2:1	4:1	M	1:1	2:1	4:1	M
0°	.319	.311	.229	.286	.422	.346	.317	.362	.371	.328	.273	.324
90°	.303	.215	.204	.240	.351	.336	.290	.326	.327	.275	.247	.283
180°	.287	.246	.212	.248	.316	.256	.252	.275	.302	.251	.232	.261
M	.303	.257	.215	.258	.363	.313	.286	.321	.333	.285	.251	.290

As scale discrepancies increased from equivalence to 2 to 1 and 4 to 1, completeness became progressively poorer (33 percent to 28 percent to 25 percent). Each additional increment of scale discrepancy resulted in significant decrement ($p < .05$) in performance.

The effect of increasing orientation discrepancy, also monotonic, was less pronounced. Completeness was reduced significantly, from 32 percent to 28 percent, as orientation misalignment increased from 0° to 90°. As misalignment increased to 180°, a statistically nonsignificant ($p > .05$) performance drop to 26 percent was observed.

Accuracy of Change Detection

Change Detection without Target Identification. Mean accuracy of change detection without target identification is shown in Table 4. The results of the analysis of variance (Appendix Table B-3) indicate that accuracy was significantly affected by scale discrepancy ($p < .01$) and by orientation misalignment ($p < .05$) but not by interpretation time ($p > .05$). None of the variables interacted with the others to influence accuracy of performance significantly.

Accuracy of change detection without target identification was neither improved nor degraded by increasing interpretation time from 3 minutes (73% accuracy) to 6 minutes (71%).

Although relatively small, consistent and reliable reduction in accuracy was found to accompany each increase in orientation misalignment. From a mean accuracy of 75 percent with no misalignment, accuracy decreased to 71 percent with 90° misalignment and to 69 percent with 180° misalignment.

The effect of scale disparity was slightly more pronounced. With two photos of equal scale, accuracy averaged approximately 77 percent. It was reduced to 73 percent with a scale of 2 to 1 and to 65 percent with a four to one disparity. The difference was statistically significant at the .01 level.

Change Detection with Target Identification. When target identification was added to the change detection task, the mean accuracy scores presented in Table 5 were obtained. Statistical analysis (Appendix Table B-4) indicated that only scale discrepancy significantly affected accuracy of performance. Accuracy did not vary as a function of time limit (58% at 3 minutes, 56% at 6 minutes). With orientation misalignment, accuracy fell off only slightly--and insignificantly--and did not increase with amount of difference.

As was found for accuracy of detection without target identification, the only statistically significant reduction in performance occurred when scale discrepancy was increased from 2 to 1 to 4 to 1 (58% vs 51%), although both scale discrepancy conditions produced accuracy scores less than the 62 percent obtained when scales for the two photos of a pair were the same.

Table 4

MEAN ACCURACY SCORES FOR CORRECT CHANGE DETECTION WITHOUT TARGET IDENTIFICATION

Orientation Misalignment	Photo Scale Disparity											
	3-Minute				6-Minute				Combined			
	1:1	2:1	4:1	M	1:1	2:1	4:1	M	1:1	2:1	4:1	M
0°	.804	.831	.674	.770	.843	.702	.667	.737	.823	.766	.671	.753
90°	.771	.713	.637	.707	.726	.775	.661	.721	.748	.744	.649	.714
180°	.797	.686	.639	.708	.693	.682	.629	.668	.745	.684	.634	.688
M	.791	.743	.650	.728	.754	.720	.652	.709	.772	.732	.651	.718

Table 5

MEAN ACCURACY SCORES FOR TARGETS DETECTED, CORRECTLY IDENTIFIED, AND ASSIGNED CORRECT CHANGE STATUS

Orientation Misalignment	Photo Scale Disparity											
	3-Minute				6-Minute				Combined			
	1:1	2:1	4:1	M	1:1	2:1	4:1	M	1:1	2:1	4:1	M
0°	.660	.683	.492	.612	.703	.550	.538	.597	.681	.616	.515	.604
90°	.615	.550	.464	.543	.575	.624	.520	.573	.595	.587	.492	.558
180°	.654	.586	.516	.585	.528	.484	.508	.507	.591	.535	.512	.546
M	.643	.606	.491	.580	.602	.553	.522	.559	.622	.579	.506	.569

Analysis of Responses in Terms of Change Status

For readers who are interested in investigating interpreter response tendencies in greater depth, change detection data in relation to type of change is presented in more detail in Appendix C. Included are summary data showing the distribution of correct and incorrect responses for each type of change (Table C-1). Figure C-1 shows the distribution of erroneous change status assignments across the change categories. To facilitate comparison between change categories having different numerical bases, the frequency data have been converted to percentages. Table C-2 gives the raw score discributions. Some cursory conclusions and speculative hypothesizing about casual factors are offered.

CONCLUSIONS

Change detection is most complete and reports on target change detected are more accurate when the aerial photos compared are the same scale and are displayed with a common directional orientation. Significant decrement in completeness and accuracy is normally associated with additional increments of scale disparity between the two photos. Both completeness and accuracy were degraded also when the two photos are not displayed in the same directional orientation. A small degree of misalignment, however, appears to affect completeness more than it does accuracy.

These results provide clear indication that display systems for comparative cover analysis should include scale rectification and reorientation capability. The functional relationship between scale disparity and orientation misalignment needs to be determined so that rectification capability may be of the required precision.

Increasing the time allowed for comparing photos can offset discrepancies in the imagery--or lack of corrective devices--with respect to completeness. Allowing additional time does not, however, appear to be effective in increasing the accuracy of change detection reports.

APPENDIXES

ADDITIONAL DESCRIPTIVE DATA FOR IMAGERY SAMPLE

Table A-1

DESCRIPTIVE DATA FOR 18 SELECTED PAIRS OF COMPARATIVE-COVER AERIAL PHOTOS

Pair No.	Photo Ident. No.	Days Elapsed	No. of Targets	Distribution by Target Classes									Distribution of Change Status				
				1	2	3	4	5	6	7	8	9	U	M	N	G	R
1	D-55/14 D-06/17	729	22			1[a]	4	7[a]	4[a]	6					12	10	
2	D-28/26 D-27/39	1	18				3	7[a]	8						4	14	
3	D-55/40 D-06/21	729	9				2	6	1							9	
4	D-55/37 D-06/13	729	4				1	1	1	1						4	
5	D-23/24 D-22/10	1	9	2			2	2	1			2	2			7	
6	D-35/84 D-45/39	6	8	1		3	2	1	1						4	4	
7	D-41/53 D-55/05	1	12				10	2							5	7	
8	D-64/10 D-64/05	0	13				12	1					2		6	5	
9	D-21/60 D-25/42	2	15				4	8	3				4	3	5	3	
10	D-42/91 D-54/57	1	12			1	5	5	1						12		
11	D-21/08 D-25/48	2	35				9	20	2			4	2		24[b]	9	

Table A-1 (Continued)

DESCRIPTIVE DATA FOR 18 SELECTED PAIRS OF COMPARATIVE-COVER AERIAL PHOTOS

Pair No.	Photo Ident. No.	Days Elapsed	No. of Targets	Distribution by Target Classes									Distribution of Change Status				
				1	2	3	4	5	6	7	8	9	U	M	N	G	R
12	D-24/43 D-06/25	3	12				8	4							12		
13	D-21/18 D-26/92	3	50				22	23[b]	5				9		28	13	
14	S-00/04 D-45/38	775	8			1[b]	4	3							6	2	
15	D-18/73 D-06/23	3	22	14[a]			7[a]	1[a]							20	2	
16	D-50/13 D-18/16	737	10	8			1	1								10	
17	D-21/05 D-25/53	2	26				11	13[a]	1	1			1		18[c]	7	
18	S-00/22 D-45/59	775	5	1			2	1	1						1	4	
TOTAL			290	26	0	6	109	106	29	8	0	6	20	3	157	110	00

[a]Includes one or more multiple-target responses considered as single targets in total column for number of targets.

[b]Includes 2 targets in non-overlap areas.

[c]Includes 7 targets in non-overlap areas.

Table A-2

DESCRIPTIVE DATA FOR STIMULUS SAMPLE

Photo Pair	Photo Identification Number	Date	Quality	Scale	Percent Common Area
1	D-06/17 D-55/14	9 Sept 62 8 Sept 64	G G	5,800 5,100	80
2	D-27/39 D-28/26	13 Sept 62 14 Sept 62	G G	4,800 900	100
3	D-06/21 D-55/40	9 Sept 62 8 Sept 64	P G	11,000 4,600	100
4	D-06/13 D-55/37	9 Sept 62 8 Sept 64	G G	4,900 4,600	65
5	D-22/10 D-23/24	11 Sept 62 12 Sept 62	F F	3,400 2,400	100
6	D-35/84 D-45/39	2 Sept 64 8 Sept 64	F F	2,800 3,000	65
7	D-41/53 D-55/05	7 Sept 64 8 Sept 64	F G	3,000 5,100	100
8	D-64/05 D-64/10	Feb 65 Feb 65	G G	4,000 4,100	95
9	D-21/60 D-25/42	10 Sept 62 12 Sept 62	F F	1,100 2,000	100
10	D-42/91 D-54/57	7 Sept 64 8 Sept 64	G F	1,500 5,300	100
11	D-21/08 D-25/48	10 Sept 62 12 Sept 62	G G	2,000 2,000	75
12	D-06/25 D-24/43	9 Sept 62 12 Sept 62	G G	11,000 2,100	100
13	D-21/18 D-26/92	10 Sept 62 13 Sept 62	G F	2,200 11,500	100
14	S-00/04 D-45/38	25 July 62 8 Sept 64	G F	2,900 3,100	85
15	D-18/73 D-06/23	6 Sept 62 9 Sept 62	VG F	3,500 11,000	100
16	D-18/16 D-50/13	29 Aug 62 5 Sept 64	F F	3,400 2,500	80
17	D-21/05 D-25/53	10 Sept 62 12 Sept 62	G G	1,900 1,800	65
18	S-00/22 D-45/59	25 July 62 8 Sept 64	G G	3,400 3,100	85

APPENDIX B RESULTS OF ANALYSES OF VARIANCE

Table B-1

ANALYSIS OF VARIANCE SUMMARY

COMPLETENESS SCORES FOR CORRECT TARGET CHANGE STATUS RESPONSES WITHOUT TARGET IDENTIFICATION

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Between Subjects				
Subjects	35	4.340	.124	---
Within Subjects				
Time (A)	1	1.188	1.188	37.03*
Orientation (B)	2	.657	.328	10.24*
Scale (C)	2	.798	.399	12.44*
AxB	2	.140	.070	2.18
BxC	4	.071	.018	.56
AxC	2	.009	.004	.14
AxBxC	4	.105	.026	.82
Photo Pair	17	14.450	.850	26.50*
Pooled Error	578	18.540	.032	---
TOTAL	647	40.299	---	---

*P < .01

Table B-2

ANALYSIS OF VARIANCE SUMMARY

COMPLETENESS SCORES FOR CORRECT TARGET CHANGE STATUS RESPONSES WITH CORRECT TARGET IDENTIFICATIONS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Between Subjects				
Subjects	35	3.370	.096	---
Within Subjects				
Time (A)	1	.630	.630	27.00*
Orientation (B)	2	.437	.218	9.37*
Scale (C)	2	.741	.370	15.88*
AxB	2	.108	.054	2.31
BxC	4	.027	.007	.29
AxC	2	.007	.004	.16
AxBxC	4	.095	.024	1.02
Photo Pair	17	13.446	.791	33.92*
Pooled Error	578	13.480	.023	---
TOTAL	647	32.340	---	---

$*P < .01$

Table B-3

ANALYSIS OF VARIANCE SUMMARY

ACCURACY SCORES FOR CORRECT TARGET CHANGE STATUS RESPONSES NOT REQUIRING TARGET IDENTIFICATIONS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Between Subjects				
Subjects	35	5.634	.161	---
Within Subjects				
Time (A)	1	.061	.061	.77
Orientation (B)	2	.475	.237	3.00*
Scale (C)	2	1.642	.821	10.41**
AxB	2	.090	.045	.57
BxC	4	.118	.029	.37
AxC	2	.041	.021	.26
AxBxC	4	.443	.111	1.41
Photo Pair	17	17.048	1.003	12.72**
Pooled Error	578	45.585	.079	---
TOTAL	647	71.135	---	---

*P < .05
**P < .01

Table B-4

ANALYSIS OF VARIANCE SUMMARY

ACCURACY SCORES FOR TARGETS DETECTED, CORRECTLY IDENTIFIED,
AND ASSIGNED CORRECT CHANGE STATUS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
<u>Between Subjects</u>				
Subjects	35	5.743	.164	---
<u>Within Subjects</u>				
Time (A)	1	.071	.071	.96
Orientation (B)	2	.406	.203	2.77
Scale (C)	2	1.487	.744	10.14*
AxB	2	.323	.161	2.20
BxC	4	.232	.058	.79
AxC	2	.229	.114	1.56
AxBxC	4	.423	.106	1.44
Photo Pair	17	23.331	1.372	18.71*
Pooled Error	578	42.382	.073	---
TOTAL	647	74.632	---	---

*P < .01

APPENDIX C

CHANGE STATUS RESPONSE ANALYSIS

The accompanying tables indicate that when the same targets are present on both coverages, targets are correctly reported as unchanged 30.4% of the time. Almost half the time (46%), the unchanged targets are missed on both coverages. On 23.6% of the unchanged target presentations, the targets are incorrectly recognized as being other than the same on both members of the photo pair. When unchanged targets are incorrectly reported, they are most often thought to be "New" targets. That is, they are detected only on the more recent imagery (P_2). This result may be partially attributable to the fact that it was always the P_1 imagery which was reduced in scale relative to the P_2 imagery to achieve the desired scale discrepancy levels. However, even when no scale or orientation discrepancy existed between the P_1 and P_2 imagery, the frequency with which "New" responses were made to unchanged targets was considerably larger than for "Gone" target responses (15 and 0 for "New" and "Gone" target responses, respectively; see Table C-1). The second most frequent error response for unchanged targets was to say that they were "Moved" targets. This would seem to indicate that subjects had difficulty recognizing that the location of targets detected on both photos was the same. There is no strong indication that this location comparison becomes more difficult as the discrepancy between image samples becomes greater.

Moved targets, of which there were only three in the stimulus sample, were omitted approximately half the time (47.2%). When detected, they were correctly recognized as "Moved" targets only about half as often as they were incorrectly reported to be representative of some other change status. Fifty percent of the incorrect change status responses for moved targets were placed in the unchanged classification, again reflecting difficulty in comparing target positions. As was found for Unchanged targets, incorrect status responses for moved targets also revealed a disproportionate assignment of "New" target responses (38.9%) to "Gone" target responses (8.3%) for a situation in which the target is on both images.

The largest number of changes in status represented on the test imagery used in this study was that of "New" targets. Targets in this category were more often correctly assigned the appropriate change status designation than were any others (37.3%). Only 8.2% of the new targets were correctly detected and then incorrectly assigned a change status. When incorrect change status responses were recorded for new targets, there was about a 50% chance that the target would be called "Unchanged" and an 86.5% chance that it would be called either "Unchanged" or "Moved." These incorrect response categories imply that an inventive error has also been made, since the subject is ascribing to the earlier imagery a target which is not there.

"Gone" targets, although most often omitted (71.4%), were least often incorrectly reported (3.5%). When incorrectly assigned a change status, these targets are designated "Unchanged" 39.4% of the time and "Moved" 49.6% of the time. As with "New" targets, this type of change status error also implies that an inventive error has been made, but on the later coverage where no target actually exists.

Table C-1

SUMMARY DISTRIBUTION OF CORRECT, INCORRECT, AND OMITTED TARGET RESPONSES FOR THE DIFFERENT CHANGE STATUS CATEGORIES

(Percent)

Change Status Responses	CHANGE STATUS CATEGORIES				
	Unchanged (N = 20)[a]	Moved (N = 3)	New (N = 148)	Gone (N = 110)	Replaced (N = 0)
Correct	30.4	19.4	37.3	25.2	0
Incorrect	23.6	33.3	8.2	3.5	100
Omitted	46.0	47.2	54.5	71.4	0
TOTAL	100	100	100	100	100

[a]Number of targets of each category in the imagery

Table C-2

RAW SCORE DISTRIBUTIONS OF CHANGE STATUS RESPONSES FOR TRUE TARGET CONDITIONS

		Scale Discrepancy														
		1:1 True Change Status					2:1 True Change Status					4:1 True Change Status				
Orientation Discrepancy	Responses	U	M	N	G	R	U	M	N	G	R	U	M	N	G	R
		Three-Minute Time Limit														
0°	U	6	0	1	2	1	15	2	4	1	0	8	0	17	3	0
	M	9	1	14	6	0	1	0	7	2	0	9	0	14	5	0
	N	8	0	107	0	0	0	0	120	0	0	6	2	115	1	0
	G	0	0	1	58	0	0	0	1	65	0	0	0	1	33	0
	R	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0
90°	U	9	1	11	2	0	6	0	14	2	0	13	0	19	3	0
	M	1	2	11	0	0	6	1	13	2	0	0	0	5	3	0
	N	7	0	103	2	0	6	0	102	0	0	8	1	85	1	0
	G	3	0	1	60	0	0	1	0	40	0	0	0	1	39	0
	R	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0
180°	U	11	1	4	2	0	3	1	14	2	0	16	1	30	4	0
	M	1	0	1	3	0	0	1	4	5	0	4	2	5	4	0
	N	4	0	83	0	0	2	1	94	0	0	4	0	89	0	0
	G	1	1	21	68	0	0	0	0	37	0	1	0	2	31	0
	R	0	0	1	1	0	0	0	0	0	0	1	0	1	0	0
		Six-Minute Time Limit														
0°	U	15	1	6	6	0	13	6	7	8	0	16	0	19	6	0
	M	1	2	1	5	0	0	0	1	2	0	1	0	6	1	0
	N	7	1	150	0	0	7	0	143	0	0	5	2	140	0	0
	G	0	0	4	93	0	0	0	0	72	0	0	0	7	62	0
	R	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
90°	U	14	1	8	1	0	12	1	18	1	0	22	0	17	1	0
	M	10	0	20	11	0	2	3	6	1	0	2	2	8	1	0
	N	4	2	140	7	0	4	2	138	0	0	10	1	139	0	0
	G	1	1	2	63	0	0	0	0	67	0	0	0	1	54	0
	R	0	0	0	0	0	1	0	2	0	0	0	0	0	2	0
180°	U	11	2	8	4	0	7	0	9	2	0	22	1	29	4	0
	M	5	0	16	8	0	3	5	22	8	0	0	2	14	1	0
	N	6	1	137	0	0	6	0	126	1	0	5	1	95	0	0
	G	1	0	4	63	0	0	0	0	45	0	1	0	7	47	0
	R	0	0	1	0	0	4	0	0	0	0	0	0	0	0	0

CHANGE STATUS RESPONSES	TRUE CHANGE STATUS: Unchanged (170)	Moved (36)	New (466)	Gone (137)	Replaced (1)
Unchanged		50.0%	50.4%	39.4%	100%
Moved	32.4%		36.1%	49.6%	0%
New	58.2%	38.9%		8.8%	0%
Gone	4.7%	8.3%	11.4%		0%
Replaced	4.7%	2.8%	2.1%	2.2%	

Figure C-1. Distribution of total change status error across change status conditions. *(Figures in parentheses are Ns for the total number of change status error responses for each change status category.)*

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13. ABSTRACT

Research Note 206 reports on a study of the need for devices to rectify disparity in photo scale and orientation in comparative-cover photos as a means of facilitating detection of change in the status of targets in the area. Personnel of the Boeing Company and of the INTERPRETER TECHNIQUES Work Unit, BESRL jointly conducted an investigation to determine the extent to which completeness and accuracy of interpreters' reports of change are dependent on the essential equivalence of the imagery being compared and to determine the desirability of incorporating scale rectification and rotational capability in systems for displaying comparative cover to interpreters. A further objective was to establish the amount of scale disparity in comparative-cover photos which can be tolerated before a decrement results in interpreter performance. The experiment assessed the effects of three levels of scale discrepancy (1:1, 2:1, and 4:1), three levels of rotational discrepancy (0°, 90°, and 180°), and two time limits (3 minutes and 6 minutes) on the completeness and accuracy of change detection. Student image interpreters (N = 36) participated in the experiment under two requirements -- one to detect change in objects characterized only as target or non-target, the other to identify the target as belonging to one of nine target categories listed on a Response Code Sheet. Each of 18 different pairs of comparative-cover scenes in which tactical military targets appeared was viewed once by each subject under each of the treatment conditions. Written reports were prepared by each interpreter for the 18 photo pairs viewed. Individual responses were scored by comparing each report of a target location, identification, and change status with "interpreter truth" data--target location and change status--provided by a team of experts in BESRL. Performance evaluations were computed in terms of change detection completeness and change

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*Surveillance						
Laboratory facilities						
Psychometric procedures						
*Image interpreter performance						
Imagery display systems						
*Disparity--photo scale						
*Disparity--orientation						
*Rotational misalignment						
Comparative-cover photos						
*Aerial imagery change detection target identification						
*Scale rectification						
*Rotational capability magnification rotation						

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13. ABSTRACT continued

detection accuracy.

Significant decrements in both completeness and accuracy of target change detection were associated with scale disparity and orientation misalignment when target identification was not required. When identification was required, significant decrement in accuracy as well as completeness obtained with scale discrepancy; with orientation misalignment, however, lower detection completeness but not lower accuracy resulted. Under the longer time limit, completeness but not accuracy of change detection with or without target identification was higher. Findings of the study strongly support the recommendation for inclusion of scale rectification and orientational alignment capabilities in display systems at operational facilities.